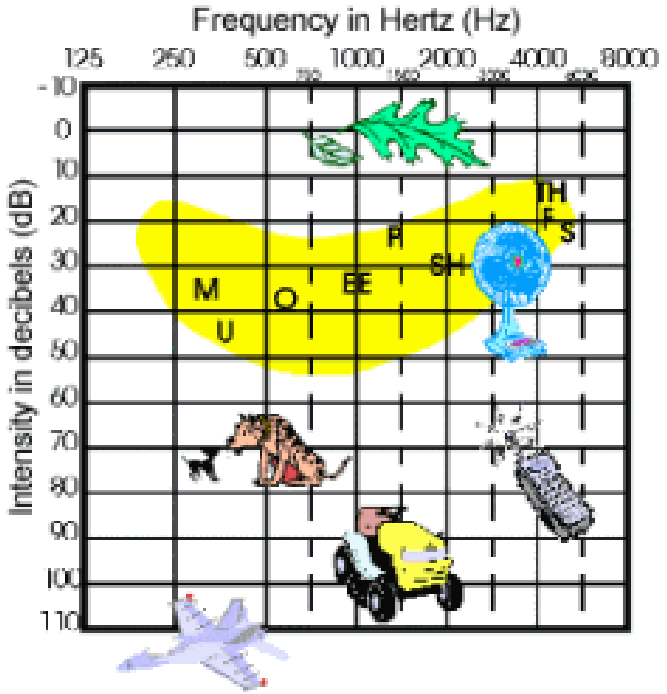
PHYSICS OF SOUND

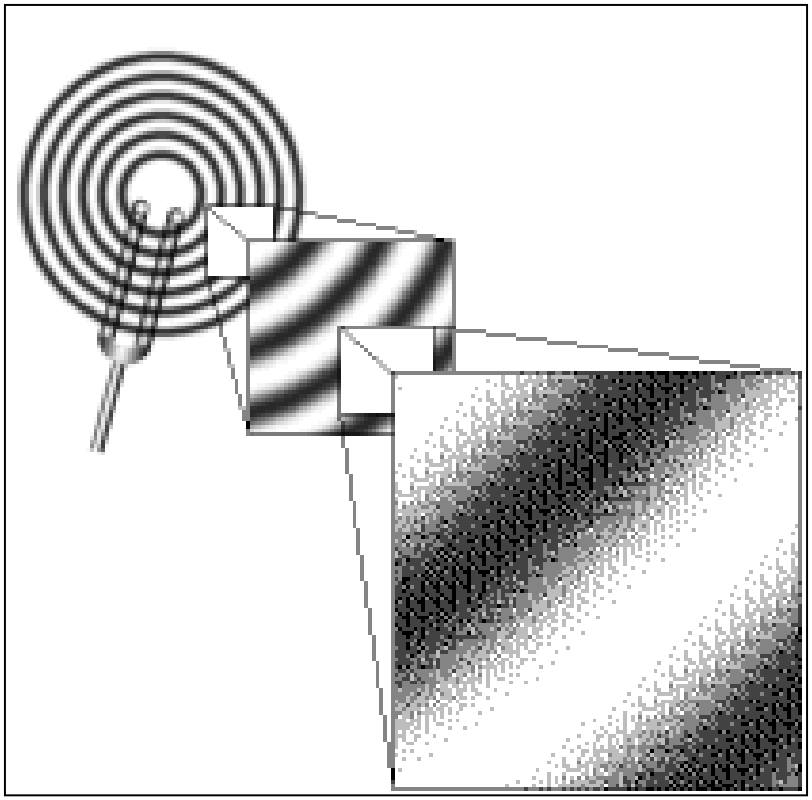
What is “Sound”?



- **The sensation resulting from stimulation of the auditory mechanism by air waves or other vibration**

Requirements For Sound…

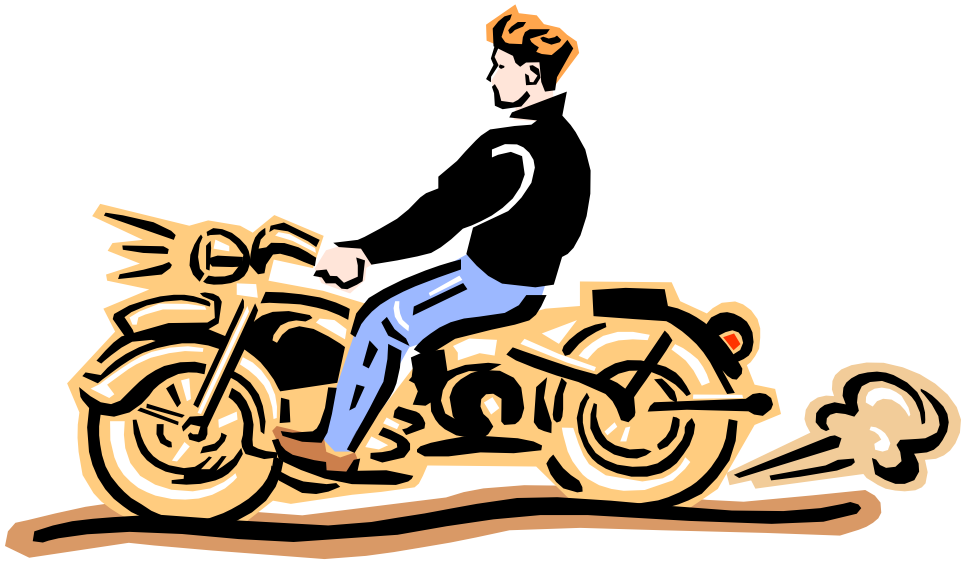
- **Source of vibration (**such as vocal folds)
- **Source of energy (**such as lungs)
- **A medium** (to carry the vibration, such as air)
- **A receiver** (such as the human ear)



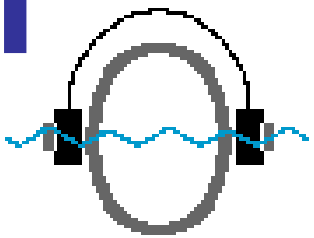
Graphic from Jay Rose website at http://www.dplay.com/book/sample.html

What is Noise?

- **Any <u>unwanted</u> sound**
- **Varies from person to person!**



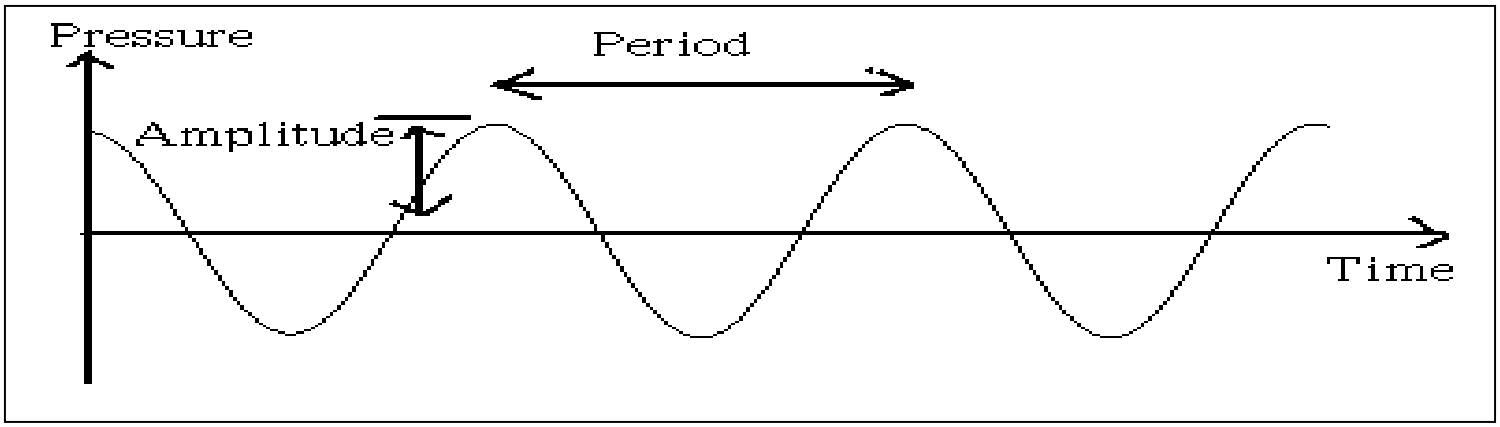
Transmission of Sound



- Sound travels in waves, leaving point of origin in a spherical pattern (in air)
  - series of compressions and rarefactions
  - Usually depicted as a sine wave
  - One complete vibration cycle, 360 degrees of motion
- Speed of Sound increases with density of the medium
  - 1100 ft/second in air
  - 4500 ft/sec in water
  - 15,000 ft/sec in steel

The Sine Wave (Pure Tone)

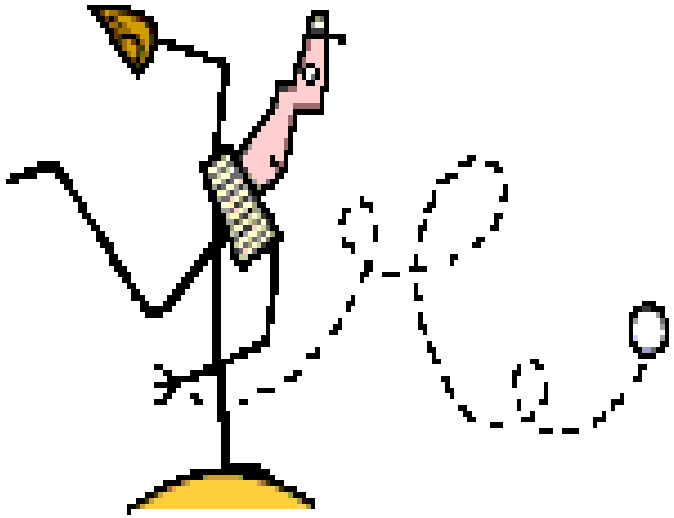
- **Horizontal Axis**: ***time in seconds***
- **Vertical Axis**: ***molecular movement***
- **Compression**: ***upward movement***
- **Rarefaction**: ***downward movement***
- **Amplitude**: ***height of wave; intensity***



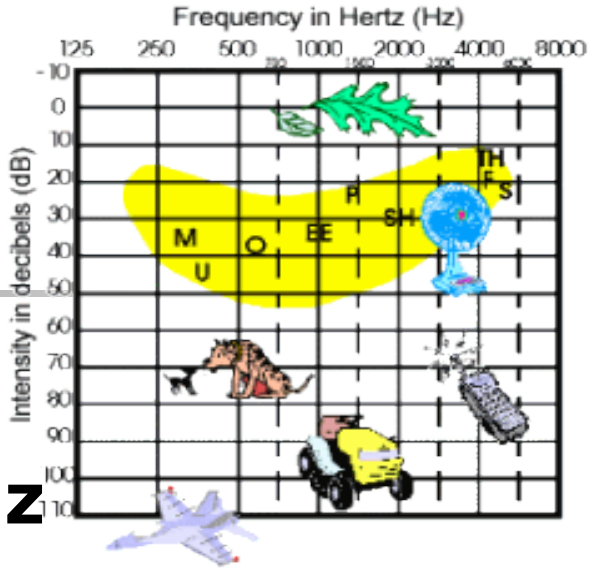
Frequency

Pitch/Hz

- Perceived as “Pitch”.
- Equal to the number of complete cycles that occur in one second.
  - one cycle = one compression and one rarefaction.
- Measured in Hertz (Hz).



Human Hearing



- **Human range: 20-20,000 Hz**
- **Human ear is most sensitive in the 1,000 - 4,000 Hz range.**
- **Less sensitive in lower frequencies.**
- **HL Scale was developed & normalized to represent human hearing.**

Intensity
Loudness/dB

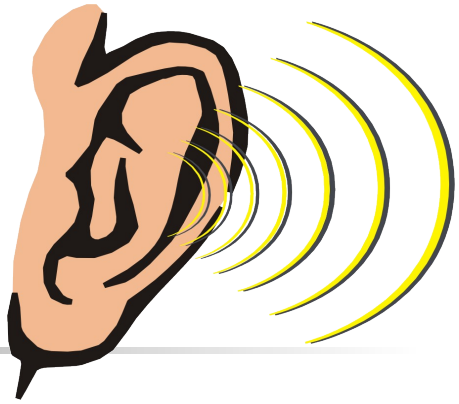
- **Perceived as “Loudness”.**
- **Intensity is expressed as the sound pressure level (SPL), which is a function of distance the vibrating object is displaced (amplitude), which depends on energy applied.**
- **Measured in decibels (dB). One dB is 1/10th of a bel.**
- **Decibels are logarithmic units. The reference used is .0002 dynes/cm2, roughly the smallest pressure that will move the TM.**

Intensity (cont.)

Why logarithms?

- **To compress the very large range of pressure our ears can hear in to a small range of numbers for convenience.**
- **0-140 dB represents a sound pressure range of 1:1,000,000,000 units (a ratio of 10 million to 1!)**

Intensity (cont.)



- 0 dB is typically the softest volume that can be heard, but sound energy is also present below 0 dB.
- Human intensity range is 0-140.
- 140 dB is the threshold of pain.
- 170-180 dB causes tissue damage.
- 180 dB+ can cause death!

INVERSE SQUARE LAW

- **Doubling the distance from a sound source decreases intensity by 6 dB.**

Doubling the Noise Source…

- **A combination of two different noise sources of equal loudness will increase the intensity by 3dB**
  - **For example, if noise source “A” is 93 dBA and noise source “B” is 93 dBA, the combined result of “A” and “B” is 96 dBA.**

Duration

Time

- **Perceived as “Time”.**
- **Can last from thousandths of a second, to several hours or all day!**
- **Occupational noise exposure varies over time.**
- **Can be constant or intermittent with continuous (steady-state) or impulse noise.**

Spectrum

Quality

- **Perceived as the "Quality" of sound.**
- **Varies from a simple pure tone to a complex mix of many frequencies and intensities; such as the human voice.**
- **Range is infinite.**

Hazardous Noise Levels Defined As

- **Continuous or steady state noise ≥ 84 dBA**
  - **Generator, Aircraft Noise, etc.**
- **Impulse/Impact noise > 140 dB peak SPL**
  - **Explosions or weapons fire**
  - **Two or more objects hitting together**
- **Intensity and duration are the two main factors that determine if a particular sound is hazardous**
- **If it is loud enough for long enough, most people will suffer hearing loss. Often takes many years!**

Sensitivity of the Human Ear (Review)

- **Frequency Range: 20 - 20,000 Hz**
- **Intensity Range: 0 - 140 dB SPL**
  - **Referred to as the dynamic range**
  - **Sounds >140dB lose tonal quality**
- **Primary speech frequencies: 500 - 4000 Hz**
  - **Frequencies above and below add quality to speech, but little intelligibility**
  - **Consonant Sounds – Primarily high freq's, convey 80% of meaning of speech**
  - **Vowel Sounds – Primarily low freq's, convey 80% of energy of sounds**
- **Threshold = The lowest intensity that the human ear can hear**

ANY QUESTIONS?